

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 837.1212/JDH

First Named Inventor or Application Identifier:

Takashi TSUDA, et al.

Express Mail Label No.

4

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. Fee Transmittal Form
2. Specification, Claims & Abstract [Total Pages: 35]
3. Drawing(s) (35 USC 113) [Total Sheets: 5]
4. Oath or Declaration [Total Pages: 4]
 - a. Newly executed (original or copy)
 - b. Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed)
 - i. DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. Incorporation by Reference (usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
 - a. Computer Readable Copy
 - b. Paper Copy (identical to computer copy)
 - c. Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. Assignment Papers (cover sheet & document(s))
9. 37 CFR 3.73(b) Statement (when there is an assignee) Power of Attorney
10. English Translation Document (if applicable)
11. Information Disclosure Statement (IDS)/PTO-1449 Copies of IDS Citations
12. Preliminary Amendment
13. Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. Small Entity Statement(s) Statement filed in prior application, status still proper and desired.
15. Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. Other:

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

Continuation Divisional Continuation-in-part (CIP) of prior application No: /

18. CORRESPONDENCE ADDRESS

STAAS & HALSEY
Attn: James D. Halsey, Jr.
700 Eleventh Street, N.W., Suite 500
Washington, DC 20001

Telephone: (202) 434-1500
Facsimile: (202) 434-1501

**METHOD AND SYSTEM FOR OPTICAL TRANSMISSION
ADOPTING DISPERSION COMPENSATION**

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method and system for optical transmission adopting dispersion compensation.

Description of the Related Art

Owing to recent developments of low-loss silica optical fibers, various optical fiber communication systems each using such an optical fiber as a transmission line have been put to practical use. The optical fiber itself has a very wide band. However, a transmission capacity by the optical fiber is actually limited by a system design. The most important limitation is due to waveform distortion by chromatic dispersion occurring in the optical fiber. Further, the optical fiber attenuates an optical signal at a rate of about 0.2 dB/km, for example. Loss of the optical signal due to this attenuation has been compensated for by adopting an optical amplifier such as an erbium doped fiber amplifier (EDFA) that is a typical example. The EDFA has a gain band in a 1.55 μ m band where a silica optical fiber gives

a lowest loss.

The chromatic dispersion that is often referred to simply as dispersion is a phenomenon such that the group velocity of an optical signal in an optical fiber changes as a function of the wavelength (or frequency) of the optical signal. In a standard single-mode fiber, for example, an optical signal having a longer wavelength propagates faster than an optical signal having a shorter wavelength in a wavelength region shorter than $1.3 \mu\text{m}$, and the resultant dispersion is usually referred to as normal dispersion. In this case, the dispersion (whose unit is ps/nm/km) takes on a negative value. In contrast, an optical signal having a shorter wavelength propagates faster than an optical signal having a longer wavelength in a wavelength region longer than $1.3 \mu\text{m}$, and the resultant dispersion is usually referred to as anomalous dispersion. In this case, the dispersion takes on a positive value.

In recent years, the nonlinearities of an optical fiber have received attention in association with an increase in optical signal power due to the use of an EDFA. The most important nonlinearity that limits a transmission capacity is an optical Kerr effect occurring in an optical fiber. The optical Kerr effect is a

phenomenon such that the refractive index of an optical fiber changes with the power or intensity of an optical signal. A change in the refractive index modulates the phase of an optical signal propagating in an optical fiber, resulting in the occurrence of frequency (wavelength) shift near the leading edge and the trailing edge of an optical waveform. This phenomenon is known as self-phase modulation (SPM). There is a possibility that such a change in spectrum due to SPM may further enlarge the waveform distortion due to chromatic dispersion.

In this manner, the chromatic dispersion and the optical Kerr effect impart waveform distortion to an optical signal with an increase in transmission distance. Accordingly, to allow long-haul transmission by an optical fiber while ensuring a transmission quality, the chromatic dispersion and the nonlinearity must be controlled, compensated, or suppressed.

As a method for compensating for dispersion in an optical fiber transmission system, a method using a dispersion compensator is known. For example, the dispersion compensator is configured so as to include a dispersion compensating fiber (DCF) having such a dispersion as canceling the dispersion of an optical fiber transmission line.

Known as a form of the optical fiber transmission system is a linear repeater system configured by connecting a plurality of segments each formed from an optical fiber and providing an optical amplifier at each connection point of these segments. This kind of system usually includes a plurality of dispersion compensators, and each dispersion compensator is provided in association with an optical transmitter, each optical amplifier, or an optical receiver. Each dispersion compensator is designed so that the total dispersion over the optical fiber transmission line is made to fall within tolerance by the addition of a dispersion given by each dispersion compensator. Accordingly, if there are variations in length of the optical fiber forming each segment, each dispersion compensator cannot be easily designed.

In another respect, the optical fiber to be used as the optical fiber transmission line is of various kinds such as a single-mode fiber (SMF) having a zero-dispersion wavelength of about $1.3 \mu\text{m}$ and a dispersion shifted fiber (DSF) having a zero-dispersion wavelength of about $1.55 \mu\text{m}$. The SMF has a low loss in a wavelength band of $1.55 \mu\text{m}$, but has a relatively large dispersion (e.g., 18 ps/nm/km) in this wavelength band. The SMF is

widely installed at present, and can also support WDM (wavelength division multiplexing) transmission. On the other hand, the DSF is a fiber having a zero-dispersion wavelength shifted into a $1.55-\mu\text{m}$ band that is a low-loss wavelength band, and the amount of installation of the DSF is yet small at present. Further, the DSF is susceptible to nonlinearity in WDM transmission. To reduce the susceptibility to nonlinearity, an NZ (nonzero)-DSF having slight dispersion in the $1.55-\mu\text{m}$ band has also been developed.

Also in such a case that a plurality of segments formed from various kinds of optical fibers are mixed, the placement of dispersion compensators and the distribution of dispersion compensation amounts are important in system design, and each dispersion compensator cannot be easily designed.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method and system for optical transmission in which dispersion compensators can be easily designed.

In accordance with a first aspect of the present invention, there is provided a method for optical transmission adopting dispersion compensation, comprising

the steps of (a) providing an optical fiber transmission line composed of a plurality of segments each having a length falling within a predetermined range; (b) providing an optical transmitter for supplying an optical signal to the optical fiber transmission line at one end of the optical fiber transmission line; (c) providing an optical receiver for receiving the optical signal from the optical fiber transmission line at the other end of the optical fiber transmission line; (d) providing an optical amplifier between any two adjacent ones of the segments; and (e) providing a dispersion compensator in association with each of the optical transmitter, the optical receiver, and the optical amplifier; the dispersion compensator providing a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range.

According to this method, each dispersion compensator can be configured so as to have a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range. For example, by preparing several kinds of dispersion compensators providing different dispersions and suitably applying to each segment the dispersion compensator selected according to the length of the segment, the

total dispersion over the optical fiber transmission line can be easily made to fall within tolerance, thereby easily designing each dispersion compensator. Thus, the object of the present invention can be achieved.

In accordance with a second aspect of the present invention, there is provided a method for optical transmission adopting dispersion compensation, comprising the steps of (a) providing an optical fiber transmission line including at least one first segment formed from a single-mode fiber and at least one second segment formed from a dispersion shifted fiber; (b) providing an optical transmitter for supplying an optical signal to the optical fiber transmission line at one end of the optical fiber transmission line; (c) providing an optical receiver for receiving the optical signal from the optical fiber transmission line at the other end of the optical fiber transmission line; (d) providing an optical amplifier between any two adjacent ones of the segments; and (e) providing a dispersion compensator in association with each of the optical transmitter, the optical receiver, and the optical amplifier except that corresponding to at least one end of the second segment.

In accordance with a third aspect of the present invention, there is provided a system for optical

transmission adopting dispersion compensation, comprising an optical fiber transmission line composed of a plurality of segments each having a length falling within a predetermined range; an optical transmitter for supplying an optical signal to the optical fiber transmission line from one end thereof; an optical receiver for receiving the optical signal from the other end of the optical fiber transmission line; an optical amplifier provided between any two adjacent ones of the segments; and a dispersion compensator provided in association with each of the optical transmitter, the optical receiver, and the optical amplifier; the dispersion compensator providing a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range.

In accordance with a fourth aspect of the present invention, there is provided a system for optical transmission adopting dispersion compensation, comprising an optical fiber transmission line including at least one first segment formed from a single-mode fiber and at least one second segment formed from a dispersion shifted fiber; an optical transmitter for supplying an optical signal to the optical fiber transmission line from one end thereof; an optical receiver for receiving the

optical signal from the other end of the optical fiber transmission line; an optical amplifier provided between any two adjacent ones of the segments; and a dispersion compensator provided in association with each of the optical transmitter, the optical receiver and the optical amplifier except that corresponding to at least one end of the second segment.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing some preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing a preferred embodiment of the system for optical transmission according to the present invention;

FIGS. 2A, 2B, and 2C are block diagrams showing preferred embodiments of an optical transmitter, an optical amplifier, and an optical receiver in one-channel transmission, respectively;

FIGS. 3A, 3B, and 3C are block diagrams showing

preferred embodiments of the optical transmitter, the optical amplifier, and the optical receiver in WDM (wavelength division multiplexing) transmission;

FIG. 4 is a graph showing dispersion characteristics of optical fibers applicable to the present invention; and

FIG. 5 is a diagram showing an example of a dispersion map obtained by the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some preferred embodiments of the present invention will now be described in detail with reference to the attached drawings.

FIG. 1 is a block diagram showing a preferred embodiment of the system for optical transmission according to the present invention. This system has an optical transmitter 2, an optical receiver 4, and an optical fiber transmission line (optical fiber span) 6 connecting the optical transmitter 2 and the optical receiver 4. The optical fiber transmission line 6 is composed of a plurality of (e.g., four as shown) segments 8(#1) to 8(#4) each having a length falling within a predetermined range. An optical amplifier for compensating for the loss of an optical signal is

provided between any two adjacent ones of the segments 8(#1) to 8(#4). More specifically, an optical amplifier 10(#1) is provided between the segments 8(#1) and 8(#2); an optical amplifier 10(#2) is provided between the segments 8(#2) and 8(#3); and an optical amplifier 10(#3) is provided between the segments 8(#3) and 8(#4).

In the case of one-channel transmission not adopting WDM (wavelength division multiplexing), the optical transmitter 2 launches an optical signal of one channel into the optical fiber transmission line 6, whereas in the case of adopting WDM, the optical transmitter 2 launches WDM signal light obtained by wavelength division multiplexing a plurality of optical signals having different wavelengths into the optical fiber transmission line 6. The optical receiver 4 receives the optical signal or the WDM signal light from the optical fiber transmission line 6.

FIGS. 2A, 2B, and 2C are block diagrams showing preferred embodiments of the optical transmitter 2, each optical amplifier 10 (each of the optical amplifiers 10(#1), 10(#2), and 10(#3)), and the optical receiver 4 in one-channel transmission, respectively. As shown in FIG. 2A, the optical transmitter 2 includes an E/O (electro/optic) converter 12 for converting an electrical

signal corresponding to transmission data into an optical signal, and a postamplifier 14 for amplifying the optical signal. The optical signal amplified by the postamplifier 14 is launched from an output port 16 into the first segment 8(#1) of the optical fiber transmission line 6. A dispersion compensator DC is provided between the E/O converter 12 and the postamplifier 14.

As shown in FIG. 2B, the optical amplifier 10 includes a front-stage amplifier 22 and a rear-stage amplifier 24 cascaded between an input port 18 and an output port 20. A dispersion compensator DC is provided between the front-stage amplifier 22 and the rear-stage amplifier 24.

As shown in FIG. 2C, the optical receiver 4 includes a preamplifier 28 for amplifying an optical signal from an input port 26 connected to the fourth segment 8(#4) of the optical fiber transmission line 6, and an O/E (opto/electric) converter 30 for converting the amplified optical signal into an electrical signal. A dispersion compensator DC is provided between the preamplifier 28 and the O/E converter 30. Each dispersion compensator DC provides a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range of length of each of

the segments 8(#1) to 8(#4). Examples of this setting of the dispersion will be hereinafter described.

FIGS. 3A, 3B, and 3C are block diagrams showing preferred embodiments of the optical transmitter 2, each optical amplifier 10, and the optical receiver 4 in WDM transmission. As shown in FIG. 3A, the optical transmitter 2 includes a plurality of E/O converters 32 for outputting a plurality of optical signals having different wavelengths λ_1 to λ_n , an optical multiplexer (MUX) 34 for wavelength division multiplexing these optical signals to output resultant WDM signal light, and a front-stage amplifier 36 and a rear-stage amplifier 38 cascaded with each other to amplify the WDM signal light. The WDM signal light is launched from an output port 40 into the first segment 8(#1) of the optical fiber transmission line 6. A dispersion compensator DC is provided between the front-stage amplifier 36 and the rear-stage amplifier 38. Each E/O converter 32 functions to convert an electrical signal corresponding to transmission data into an optical signal. The plural E/O converters 32 are respectively connected to a plurality of input ports of the optical multiplexer 34. A single output port of the optical multiplexer 34 is connected to the front-stage amplifier 36.

As shown in FIG. 3B, the optical amplifier 10 includes a front-stage amplifier 46 and a rear-stage amplifier 48 cascaded between an input port 42 and an output port 44. A dispersion compensator DC is provided between the front-stage amplifier 46 and the rear-stage amplifier 48.

As shown in FIG. 3C, the optical receiver 4 includes a front-stage amplifier 52 and a rear-stage amplifier 54 cascaded with each other to amplify WDM signal light from an input port 50 connected to the fourth segment 8(#4) of the optical fiber transmission line 6, an optical demultiplexer (DMUX) 56 for separating the amplified WDM signal light into a plurality of optical signals having different wavelengths λ_1 to λ_n , and a plurality of O/E converters 58 for respectively converting these optical signals into electrical signals. A dispersion compensator DC is provided between the front-stage amplifier 52 and the rear-stage amplifier 54. A single input port of the optical demultiplexer 56 is connected to the rear-stage amplifier 54, and a plurality of output ports of the optical demultiplexer 56 are respectively connected to the plural O/E converters 58. In each of the one-channel transmission and the WDM transmission mentioned above, front-stage amplifiers and

rear-stage amplifiers are combined as required. In this case, by using a relatively low-noise amplifier as each front-stage amplifier and a relatively high-output amplifier as each rear-stage amplifier, a reduction in noise figure due to loss by each dispersion compensator can be prevented and a required high output can also be obtained. Further, in each of the optical transmitter and the optical receiver for WDM transmission, the combination of the front-stage amplifier and the rear-stage amplifier is intended to easily make flat the wavelength characteristic of gain.

FIG. 4 is a graph showing dispersion characteristics of optical fibers usable as each segment 8. In FIG. 4, the vertical axis represents dispersion (ps/nm/km) and the horizontal axis represents wavelength (μm). In the case that a general silica-based single-mode fiber (SMF) is used as each segment 8, the zero-dispersion wavelength of the SMF is about $1.3 \mu\text{m}$. In this case, the dispersion falls in a region of anomalous dispersion for an optical signal having a wavelength longer than the zero-dispersion wavelength, and has a positive value. Conversely, the dispersion falls in a region of normal dispersion for an optical signal having a wavelength shorter than the zero-dispersion wavelength,

and has a negative value.

In the case of using an SMF as each segment 8, the wavelength of an optical signal is set to fall in a 1.55 μm band (e.g., 1.50 to 1.60 μm) giving a minimum loss in the SMF, so as to minimize the loss and maximize the length of each segment 8. Accordingly, the dispersion for the optical signal falls always in a region of anomalous dispersion. Accordingly, in the case that all the segments 8 are provided by SMFs, it is desirable to perform dispersion compensation in each segment 8. An example of setting on distribution or the like of dispersion compensation amounts in this case will be hereinafter described.

In the case that a dispersion shifted fiber (DSF) is used as each segment 8, the zero-dispersion wavelength of the DSF is about 1.55 μm . Also in this case, the dispersion falls in a region of anomalous dispersion for an optical signal having a wavelength longer than the zero-dispersion wavelength, and has a positive value. Conversely, the dispersion falls in a region of normal dispersion for an optical signal having a wavelength shorter than the zero-dispersion wavelength, and has a negative value.

Because the wavelength giving a minimum loss in the

DSF is also equal to about $1.55 \mu\text{m}$, the wavelength of an optical signal is set to fall in a $1.55 \mu\text{m}$ band. Accordingly, whether the dispersion in the DSF falls in a region of anomalous dispersion or in a region of normal dispersion is determined according to the correlation between the actual wavelength of an optical signal and the zero-dispersion wavelength of the DSF. However, as far as the wavelength of an optical signal is set in a $1.55-\mu\text{m}$ band, the dispersion (ps/nm) in the segment is sufficiently small irrespective of whether the dispersion in the DSF falls in an anomalous dispersion region or in a normal dispersion region, so that no dispersion compensation may be required in the segment formed from a DSF. In other words, in the case that at least one segment formed from a DSF and at least one segment formed from an SMF are mixed, there is a possibility that the application of a dispersion compensator to the segment formed of a DSF may be omitted. An example of such a configuration will also be hereinafter described.

Table 1

Segment Distance (km)	Dispersion Compensation Amount (ps/nm)		
	Optical Transmitter	Optical Amplifier	Optical Receiver
0-20	-600	-200	-200
20-40		-400	
40-60		-700	-600
60-80		-1000	

Table 1 shows an example of setting of the dispersion compensation amount of each dispersion compensator DC in the case that all the segments 8(#1) to 8(#4) shown in FIG. 1 are SMFs. In this example, the dispersion (ps/nm; ditto for the following) of the dispersion compensation DC in the optical transmitter 2 is set to -600. The dispersions of the dispersion compensators DC in the optical amplifiers 10(#1) to 10(#3) and in the optical receiver 4 are set according to the distance (km; ditto for the following) of the corresponding segment 8 immediately upstream of each optical component. For example, the dispersion of the dispersion compensator DC in the optical amplifier 10(#1) is set in such a manner that when the distance of the segment 8(#1) is less than 20, the dispersion is set to -200; when the distance of the segment 8(#1) is in the range from 20 to less than 40, the dispersion is set to -400; when the distance of the segment 8(#1) is in the

range from 40 to less than 60, the dispersion is set to -700; and when the distance of the segment 8(#1) is in the range from 60 to less than 80, the dispersion is set to -1000. Similarly, the dispersion of the dispersion compensator DC in the optical amplifier 10(#2) is set according to the distance of the segment 8(#2), and the dispersion of the dispersion compensator DC in the optical amplifier 10(#3) is set according to the distance of the segment 8(#3). Further, the dispersion of the dispersion compensator DC in the optical receiver 4 is set in such a manner that when the distance of the segment 8(#4) is less than 40, the dispersion is set to -200, and when the distance of the segment 8(#4) is in the range from 40 to less than 80, the dispersion is set to -600.

According to this preferred embodiment, the total dispersion over the optical fiber transmission line 6 can be easily made to fall within tolerance, so that the waveform distortion due to dispersion can be suppressed to thereby improve a transmission quality. Further, since the distance of each segment is set within a predetermined range (0-80 in this example), a transmission line loss can be easily compensated by each optical amplifier 10. Further, since it is not necessary

to increase the output power of each optical amplifier 10 to a given value or more, the waveform distortion due to nonlinearity can be suppressed to thereby improve a transmission quality. Further, since each dispersion compensator DC provides a dispersion selected from a plurality of stepwise varying dispersions determined according to a predetermined distance range (0-20, 20-40, 40-60, or 60-80), each dispersion compensator DC can be selected from a given menu. That is, several kinds of dispersion compensators having different dispersions may be prepared in advance and they may be selectively used according to the distance of each segment 8, thereby allowing easy construction of a system. Thus, it is possible to provide a method and system for optical transmission in which dispersion compensators can be easily designed.

There will now be described an example of setting of the dispersion compensation amount of each dispersion compensator DC in the case that a DSF is applied to at least one of the segments 8(#1) to 8(#4).

Table 2

DSF Applied Segment	Dispersion Compensation Amount (ps/nm)					
	Optical Transmitter	Optical Amplifiers			Optical Receiver	
		#1	#2	#3		
First Segment	0	-600	-1000		-1000	-600
Second Segment	-600	-800	0			-800
Third Segment		-1000	-800	0		
Fourth Segment			-1000	-600		0

Table 2 shows an example of setting of the dispersion compensation amount of each dispersion compensator DC in the case that a DSF is applied to one of the segments 8(#1) to 8(#4) shown in FIG. 1 and SMFs are applied to the other segments. In the case that a DSF is applied to the first segment 8(#1), the dispersion compensator DC in the optical transmitter 2 is omitted, the dispersion of the dispersion compensator DC in the optical amplifier 10(#1) is set to -600, the dispersion of the dispersion compensator DC in the optical amplifier 10(#2) is set to -1000, the dispersion of the dispersion compensator DC in the optical amplifier 10(#3) is set to -1000, and the dispersion of the dispersion compensator DC in the optical receiver 4 is set to -600.

In the case that a DSF is applied to any one of the second segment 8(#2), the third segment 8(#3), and the

fourth segment 8(#4), the dispersion of the dispersion compensator DC in the optical transmitter 2 is set to -600. In the case that a DSF is applied to the second segment 8(#2), the dispersion of the dispersion compensator DC in the optical amplifier 10(#1) is set to -800, the dispersion compensator DC in the optical amplifier 10(#2) is omitted, the dispersion of the dispersion compensator DC in the optical amplifier 10(#3) is set to -1000, and the dispersion of the dispersion compensator DC in the optical receiver 4 is set to -800. In the case that a DSF is applied to the third segment 8(#3), the dispersion of the dispersion compensator DC in the optical amplifier 10(#1) is set to -1000, the dispersion of the dispersion compensator DC in the optical amplifier 10(#2) is set to -800, the dispersion compensator DC in the optical amplifier 10(#3) is omitted, and the dispersion of the dispersion compensator DC in the optical receiver 4 is set to -800. In the case that a DSF is applied to the fourth segment 8(#4), the dispersion of the dispersion compensator DC in the optical amplifier 10(#1) is set to -1000, the dispersion of the dispersion compensator DC in the optical amplifier 10(#2) is set to -1000, the dispersion of the dispersion compensator DC in the optical amplifier 10(#3) is set to

-600, and the dispersion compensator DC in the optical receiver 4 is omitted.

The distance of each segment is set to 70, for example. Preferably, the distance of each segment is set within a predetermined range (0-80) as in the case that SMFs only are applied.

According to this preferred embodiment, a DSF is applied to any one of the segments 8(#1) to 8(#4), so that the dispersion compensator DC corresponding to one end of the segment to which the DSF is applied can be omitted. Accordingly, although a reduced number of dispersion compensators are used, the total dispersion over the optical fiber transmission line 6 can be easily made to fall within tolerance, so that the waveform distortion due to dispersion can be suppressed to thereby improve a transmission quality. Further, like the previous preferred embodiment, each dispersion compensator DC can be selected from a given menu, so that it is possible to provide a method and system for optical transmission in which dispersion compensators can be easily designed.

While a DSF is applied to only one segment in the above description related to Table 2, a plurality of DSFs may be applied to two or more segments.

Thus, by applying a DSF to at least one of the segments 8(#1) to 8(#4), the dispersion compensator DC corresponding to at least one end of each segment to which the DSF is applied can be omitted.

FIG. 5 is a diagram showing an example of a dispersion map obtained by the present invention. In FIG. 5, the vertical axis represents dispersion, and the horizontal axis represents position or distance on the optical fiber transmission line 6. Specifically, FIG. 5 shows a dispersion map in the case that a DSF is applied to the second segment 8(#2) in relation to Table 2. Although the dispersion compensator DC in the optical amplifier 10(#2) is omitted in this case as described above, it is understood from FIG. 5 that the total dispersion over the optical fiber transmission line 6 is made to fall within tolerance by the application of the present invention.

According to the present invention as described above, it is possible to provide a method and system for optical transmission in which dispersion compensators can be easily designed. The effects obtained by the specific preferred embodiments of the present invention have been described, so the description thereof will be omitted herein.

The present invention is not limited to the details of the above described preferred embodiments. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

WHAT IS CLAIMED IS:

1. A method for optical transmission adopting dispersion compensation, comprising the steps of:
 - (a) providing an optical fiber transmission line composed of a plurality of segments each having a length falling within a predetermined range;
 - (b) providing an optical transmitter for supplying an optical signal to said optical fiber transmission line at one end of said optical fiber transmission line;
 - (c) providing an optical receiver for receiving said optical signal from said optical fiber transmission line at the other end of said optical fiber transmission line;
 - (d) providing an optical amplifier between any two adjacent ones of said segments; and
 - (e) providing a dispersion compensator in association with each of said optical transmitter, said optical receiver, and said optical amplifier;

 said dispersion compensator providing a dispersion selected from a plurality of stepwise varying dispersions determined according to said predetermined range.
2. A method according to claim 1, wherein each of said segments is formed from a single-mode fiber having a zero-dispersion wavelength of about 1.3 μm .

3. A method according to claim 1, wherein said optical signal has a wavelength of about 1.55 μ m.

4. A method according to claim 1, wherein said optical signal comprises a plurality of optical signals having different wavelengths obtained by wavelength division multiplexing.

5. A method for optical transmission adopting dispersion compensation, comprising the steps of:

(a) providing an optical fiber transmission line including at least one first segment formed from a single-mode fiber and at least one second segment formed from a dispersion shifted fiber;

(b) providing an optical transmitter for supplying an optical signal to said optical fiber transmission line at one end of said optical fiber transmission line;

(c) providing an optical receiver for receiving said optical signal from said optical fiber transmission line at the other end of said optical fiber transmission line;

(d) providing an optical amplifier between any two adjacent ones of said segments; and

(e) providing a dispersion compensator in association with each of said optical transmitter, said optical receiver, and said optical amplifier except that

corresponding to at least one end of said second segment.

6. A method according to claim 5, wherein said single-mode fiber has a zero-dispersion wavelength of about $1.3 \mu\text{m}$, and said dispersion shifted fiber has a zero-dispersion wavelength of about $1.55 \mu\text{m}$.

7. A method according to claim 5, wherein said optical signal has a wavelength of about $1.55 \mu\text{m}$.

8. A method according to claim 5, wherein said optical signal comprises a plurality of optical signals having different wavelengths obtained by wavelength division multiplexing.

9. A system for optical transmission adopting dispersion compensation, comprising:

an optical fiber transmission line composed of a plurality of segments each having a length falling within a predetermined range;

an optical transmitter for supplying an optical signal to said optical fiber transmission line from one end thereof;

an optical receiver for receiving said optical signal from the other end of said optical fiber transmission line;

an optical amplifier provided between any two adjacent ones of said segments; and

a dispersion compensator provided in association with each of said optical transmitter, said optical receiver, and said optical amplifier;

 said dispersion compensator providing a dispersion selected from a plurality of stepwise varying dispersions determined according to said predetermined range.

10. A system according to claim 9, wherein each of said segments is formed from a single-mode fiber having a zero-dispersion wavelength of about 1.3 μm .

11. A system according to claim 9, wherein said optical signal has a wavelength of about 1.55 μm .

12. A system according to claim 9, wherein:

 said optical transmitter comprises an E/O converter for converting an electrical signal into said optical signal, and a postamplifier for amplifying said optical signal;

 said dispersion compensator being provided between said E/O converter and said postamplifier.

13. A system according to claim 9, wherein:

 said optical amplifier comprises a front-stage amplifier and a rear-stage amplifier cascaded with each other;

 said dispersion compensator being provided between said front-stage amplifier and said rear-stage amplifier.

14. A system according to claim 9, wherein:

 said optical receiver comprises a preamplifier for amplifying said optical signal, and an O/E converter for converting said optical signal into an electrical signal; said dispersion compensator being provided between said preamplifier and said O/E converter.

15. A system according to claim 9, wherein:

 said optical transmitter comprises a plurality of E/O converters each for converting an electrical signal into said optical signal, a front-stage amplifier and a rear-stage amplifier cascaded with each other, and an optical multiplexer having a plurality of input ports respectively connected to said plurality of E/O converters and an output port connected to said front-stage amplifier;

 said dispersion compensator being provided between said front-stage amplifier and said rear-stage amplifier.

16. A system according to claim 9, wherein:

 said optical receiver comprises a front-stage amplifier and a rear-stage amplifier cascaded with each other, a plurality of O/E converters each for converting said optical signal into an electrical signal, and an optical demultiplexer having an input port connected to said rear-stage amplifier and a plurality of output ports

respectively connected to said plurality of O/E converters;

 said dispersion compensator being provided between said front-stage amplifier and said rear-stage amplifier.

17. A system for optical transmission adopting dispersion compensation, comprising:

 an optical fiber transmission line including at least one first segment formed from a single-mode fiber and at least one second segment formed from a dispersion shifted fiber;

 an optical transmitter for supplying an optical signal to said optical fiber transmission line from one end thereof;

 an optical receiver for receiving said optical signal from the other end of said optical fiber transmission line;

 an optical amplifier provided between any two adjacent ones of said segments; and

 a dispersion compensator provided in association with each of said optical transmitter, said optical receiver and said optical amplifier except that corresponding to at least one end of said second segment.

18. A system according to claim 17, wherein said first segment has a zero-dispersion wavelength of about

1.3 μm , and said second segment has a zero-dispersion wavelength of about 1.55 μm .

19. A system according to claim 17, wherein said optical signal has a wavelength of about 1.55 μm .

20. A system according to claim 17, wherein:
said optical transmitter comprises an E/O converter for converting an electrical signal into said optical signal, and a postamplifier for amplifying said optical signal;

 said dispersion compensator being provided between said E/O converter and said postamplifier.

21. A system according to claim 17, wherein:
said optical amplifier comprises a front-stage amplifier and a rear-stage amplifier cascaded with each other;

 said dispersion compensator being provided between said front-stage amplifier and said rear-stage amplifier.

22. A system according to claim 17, wherein:
said optical receiver comprises a preamplifier for amplifying said optical signal, and an O/E converter for converting said optical signal into an electrical signal;
 said dispersion compensator being provided between said preamplifier and said O/E converter.

23. A system according to claim 17, wherein:

said optical transmitter comprises a plurality of E/O converters each for converting an electrical signal into said optical signal, a front-stage amplifier and a rear-stage amplifier cascaded with each other, and an optical multiplexer having a plurality of input ports respectively connected to said plurality of E/O converters and an output port connected to said front-stage amplifier;

said dispersion compensator being provided between
said front-stage amplifier and said rear-stage amplifier.

24. A system according to claim 17, wherein:

said optical receiver comprises a front-stage amplifier and a rear-stage amplifier cascaded with each other, a plurality of O/E converters each for converting said optical signal into an electrical signal, and an optical demultiplexer having an input port connected to said rear-stage amplifier and a plurality of output ports respectively connected to said plurality of O/E converters;

said dispersion compensator being provided between
said front-stage amplifier and said rear-stage amplifier.

ABSTRACT OF THE DISCLOSURE

An optical fiber transmission line composed of a plurality of segments each having a length falling within a predetermined range is provided. An optical transmitter for supplying an optical signal to the transmission line is provided at one end of the transmission line. An optical receiver for receiving the optical signal from the transmission line is provided at the other end of the transmission line. An optical amplifier is provided between any two adjacent ones of the segments. A dispersion compensator is provided in association with each of the optical transmitter, the optical receiver, and the optical amplifier. The dispersion compensator provides a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range. According to this method, each dispersion compensator can be configured so as to have a dispersion selected from a plurality of stepwise varying dispersions determined according to the predetermined range. For example, by preparing several kinds of dispersion compensators providing different dispersions and suitably applying to each segment the dispersion compensator selected according to the length of the segment, the total dispersion over the optical fiber

transmission line can be easily made to fall within tolerance, thereby easily designing each dispersion compensator.

FIG. 1

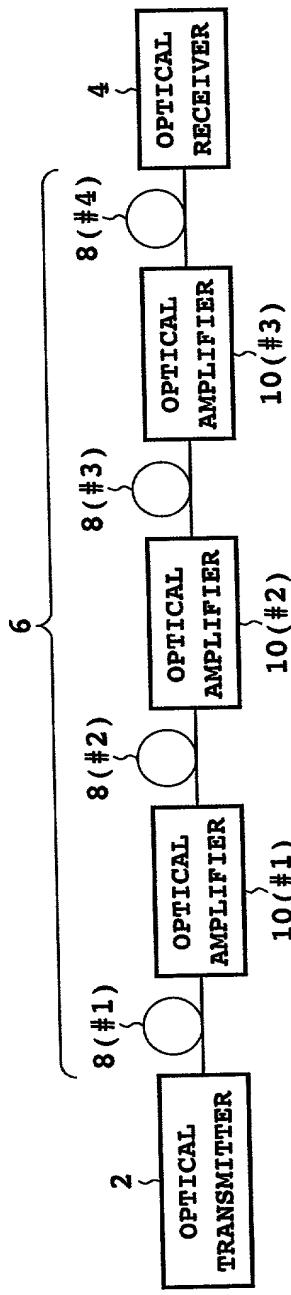


FIG. 2 A

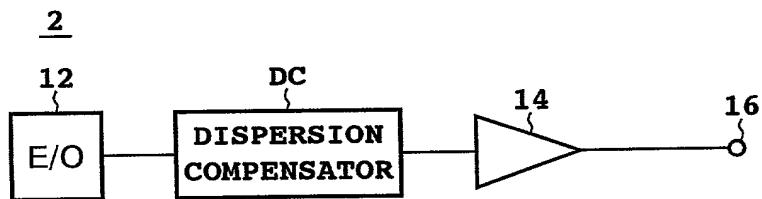


FIG. 2 B

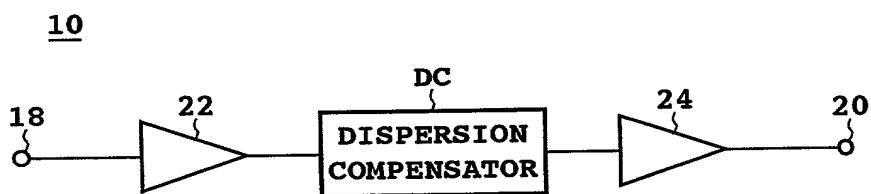


FIG. 2 C

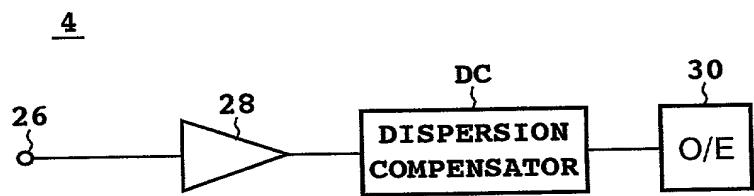


FIG. 3 A

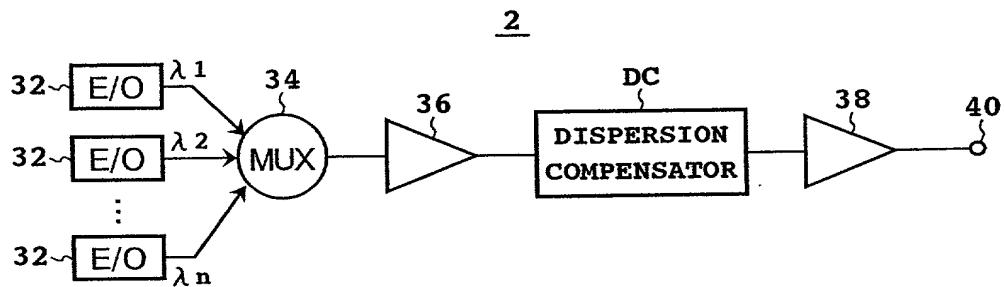


FIG. 3 B

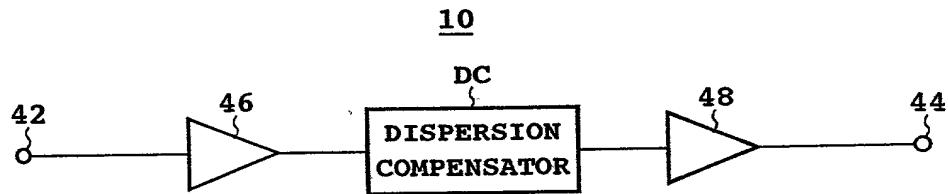


FIG. 3 C

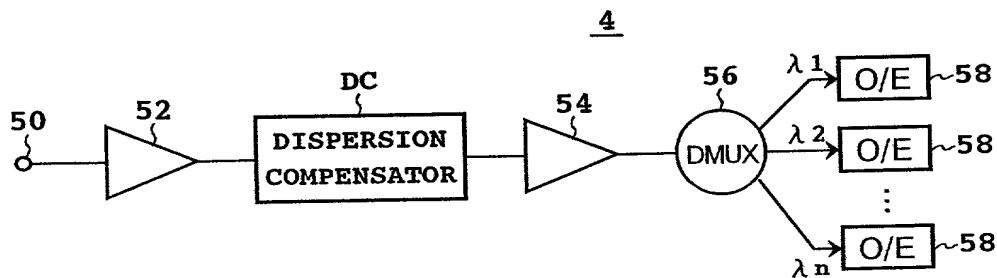
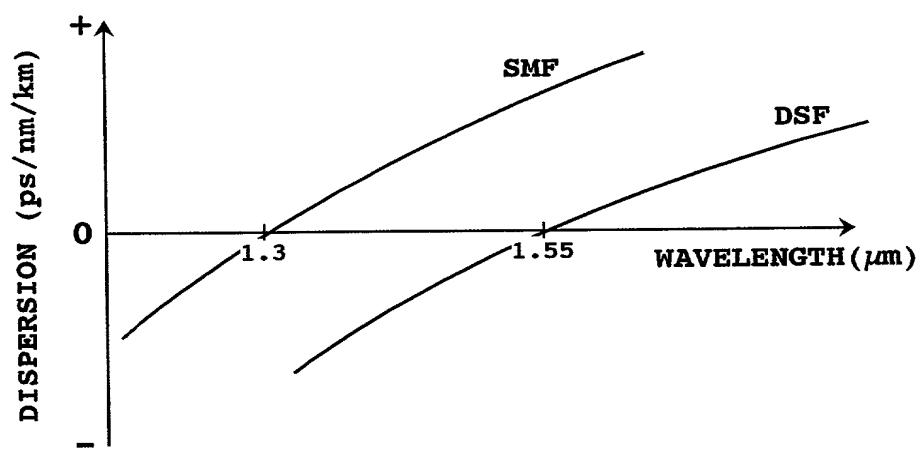
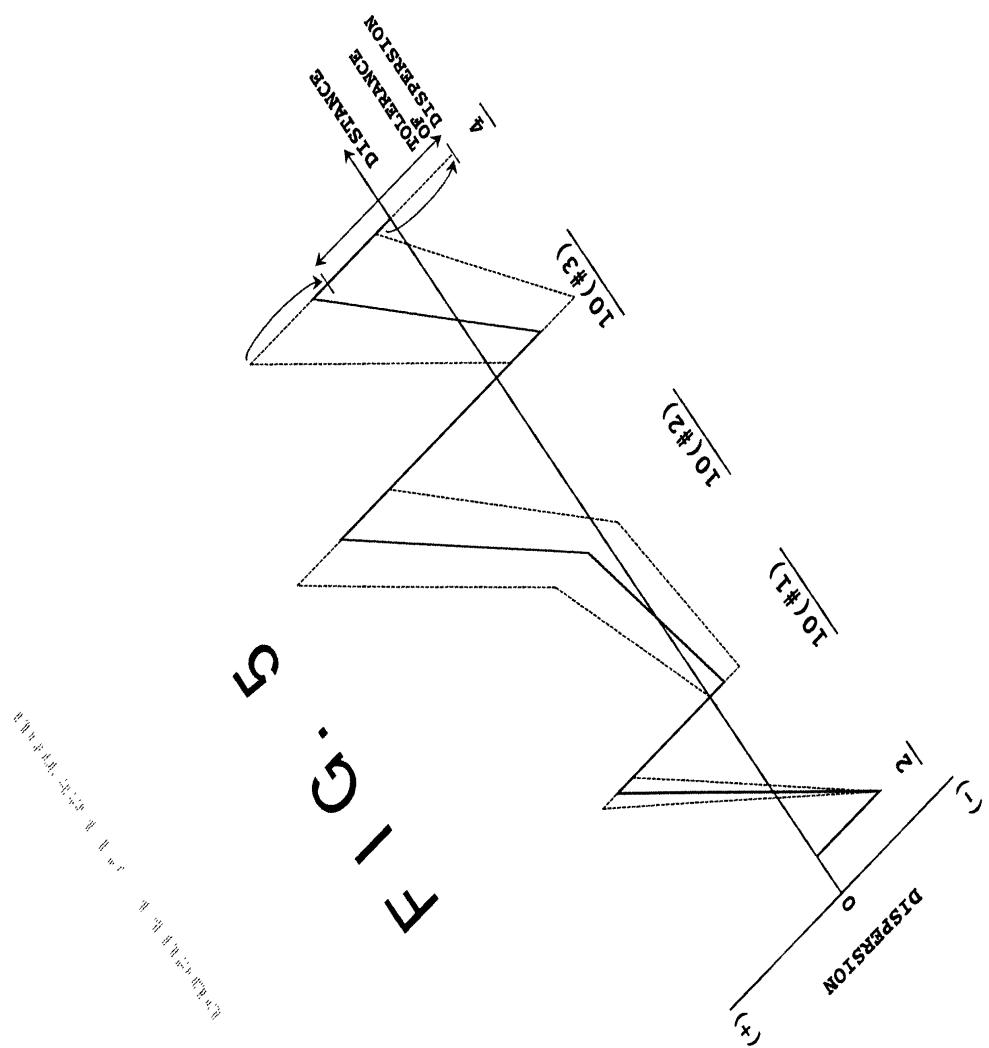


FIG. 4





Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下の氏名の発明者として、私は以下の通り宣言します。

As a below named Inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明について請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND SYSTEM FOR OPTICAL
TRANSMISSION ADOPTING DISPERSION
COMPENSATION

上記発明の明細書（下記の欄でx印がついていない場合は、本欄に添付）は、

the specification of which is attached hereto unless the following box is checked:

 一月一日に提出され、米国出願番号または特許協定条約
国際出願番号を_____とし、
(該当する場合)_____に訂正されました。 was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
(if applicable).私は、特許請求範囲を含む上記訂正後の明細書を検討し、
内容を理解していることをここに表明します。I hereby state that I have reviewed and understand the contents of
the above identified specification, including the claims, as
amended by any amendment referred to above.私は、連邦規則法典第37編第1条56項に定義されると
おり、特許資格の有無について重要な情報を開示する義務が
あることを認めます。I acknowledge the duty to disclose information which is material to
patentability as defined in Title 37, Code of Federal Regulations,
Section 1.56.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基き下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365(a)項に基く国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している。本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

Prior Foreign Application(s)

外国での先行出願

11-037837

(Number)
(番号)

Japan

(Country)
(国名)(Number)
(番号)(Country)
(国名)

私は、第35編米国法典119条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

(Application No.)
(出願番号)(Filing Date)
(出願日)

私は、下記の米国法典第35編120条に基いて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条(c)に基く権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

(Application No.)
(出願番号)(Filing Date)
(出願日)(Application No.)
(出願番号)(Filing Date)
(出願日)

私は、私自身の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごく宣言を致します。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Not Claimed

優先権主張なし



16 February 1999

(Day/Month/Year Filed)
(出願年月日)(Day/Month/Year Filed)
(出願年月日)

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.)
(出願番号)(Filing Date)
(出願日)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Status: Patented, Pending, Abandoned)
(現況: 特許許可済、係属中、放棄済)(Status: Patented, Pending, Abandoned)
(現況: 特許許可済、係属中、放棄済)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration
(日本語宣言書)

委任状： 私は下記の発明者として、本出願に関する一切の手続を米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと）

James D. Halsey, Jr., 22,729; Harry John Staas, 22,010; David M. Pitcher, 25,908; John C. Garvey, 28,607; J. Randall Beckers, 30,358; William F. Herbert, 31,024; Richard A. Gollhofer, 31,106; Mark J. Henry, 36,162; Gene M. Garner II, 34,172; Michael D. Stein, 37,240; Paul I. Kravetz, 35,230; Gerald P. Joyce, III, 37,648; Todd E. Marlette, 35,269; Harlan B. Williams, Jr., 34,756; George N. Stevens, 36,938; Michael C. Soldner, 41,455; Norman L. Ourada, 41,235; Kevin R. Spivak, P-43,148; and William M. Schertler, 35,348 (agent)

書類送付先

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (list name and registration number).

Send Correspondence to:

STAAS & HALSEY
700 Eleventh Street, N.W.
Suite 500
Washington, D.C. 20001

直接電話連絡先：（名前及び電話番号）

Direct Telephone Call to: (name and telephone number)

STAAS & HALSEY
(202) 434-1500

唯一または第一発明者名		Full name of sole or first inventor	
		Takashi Tsuda	
発明者の署名	日付	Inventor's signature	Date
		/ Takashi Tsuda	
住所		Residence	October 20, 1999
		Kawasaki-shi, Japan	
国籍		Citizenship	
		Japanese	
私書箱		Post Office Address	
		C/O FUJITSU LIMITED, 1-1, Kamikodanaka	
		4-chome, Nakahara-ku, Kawasaki-shi,	
		Kanagawa 211-8588 Japan	
第二共同発明者		Full name of second joint inventor, if any	
		Kazuo Yamane	
第二共同発明者	日付	Second inventor's signature	Date
		/ Kazuo Yamane	
住所		Residence	October 20, 1999
		Kawasaki-shi, Japan	
国籍		Citizenship	
		Japanese	
私書箱		Post Office Address	
		C/O FUJITSU LIMITED, 1-1, Kamikodanaka	
		4-chome, Nakahara-ku, Kawasaki-shi,	
		Kanagawa 211-8588 Japan	

（第三以降の共同発明者についても同様に記載し、署名すること） (Supply similar information and signature for third and subsequent joint inventors.)

第三共同発明者	Full name of third joint inventor, if any Yumiko Kawasaki		
第三共同発明者	日付	Third inventor's signature	Date <i>Yumiko Kawasaki</i> October 22, 1999
住 所	Residence Shinagawa-ku, Japan		
国 籍	Citizenship Japanese		
私書箱	Post Office Address 1-6-704, Nishi-gotanda 4-chome, Shinagawa-ku, Tokyo 141-0031 Japan		
第四共同発明者	Full name of fourth joint inventor, if any Satoru Okano		
第四共同発明者	日付	Fourth inventor's signature	Date <i>Satoru Okano</i> October 26, 1999
住 所	Residence Sapporo-shi, Japan		
国 籍	Citizenship Japanese		
私書箱	Post Office Address C/O FUJITSU HOKKAIDO DIGITAL TECHNOLOGY LIMITED, 3-1, Nishi 4-chome, Kita 7-jo, Kita-ku, Sapporo-shi, Hokkaido 060-0807 Japan		
第五共同発明者	Full name of fifth joint inventor, if any		
第五共同発明者	日付	Fifth inventor's signature	Date
住 所	Residence		
国 籍	Citizenship		
私書箱	Post Office Address		
第六共同発明者	Full name of sixth joint inventor, if any		
第六共同発明者	日付	Sixth inventor's signature	Date
住 所	Residence		
国 籍	Citizenship		
私書箱	Post Office Address		

(第七以降の共同発明者についても同様に
記載し、署名をすること)

(Supply similar information and signature for
seventh and subsequent joint inventors.)